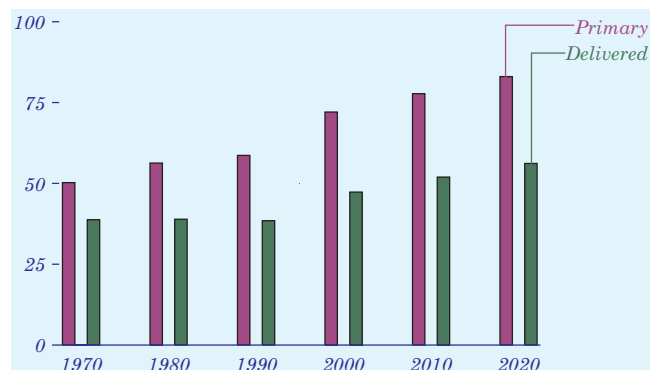


Primary and Delivered Energy Use Show Similar Growth Rates

Figure 43. Primary and delivered energy consumption, excluding transportation use, 1970-2020 (quadrillion Btu)



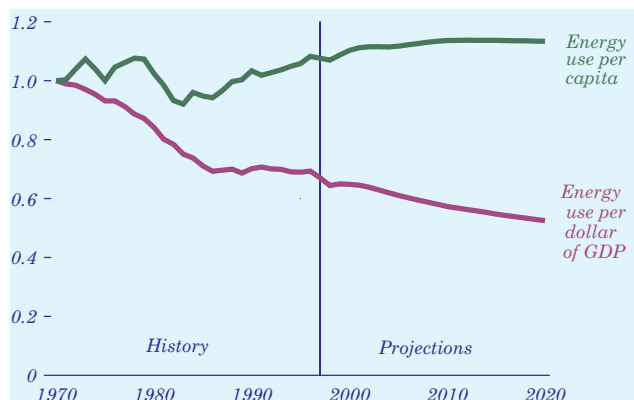
Net energy delivered to consumers represents only a part of total primary energy consumption. Primary consumption includes energy losses associated with the generation, transmission, and distribution of electricity, which are allocated to the end-use sectors (residential, commercial, and industrial) in proportion to each sector's share of electricity use [51].

How energy consumption is measured has become more important over time, as reliance on electricity has expanded. In 1970 electricity accounted for only 12 percent of energy delivered to the end-use sectors, excluding transportation. Since then, the growth in electricity use for applications such as space conditioning, consumer appliances, telecommunication equipment, and industrial machinery has resulted in greater divergence between total and delivered energy consumption (Figure 43). This trend is expected to stabilize over the forecast horizon, as more efficient generating technologies offset increased demand for electricity. Projected primary energy consumption and delivered energy consumption grow by 0.8 percent and 0.9 percent a year, respectively, excluding transportation use.

At the end-use sectoral level, tracking of primary energy consumption is necessary to link specific policies with overall goals. Carbon emissions, for example, are closely correlated with total energy consumption. In the development of carbon stabilization policies, growth rates for primary energy consumption may be more important than those for delivered energy.

Projected GDP Growth Exceeds Growth in Energy Use

Figure 44. Energy use per capita and per dollar of gross domestic product, 1970-2020 (index, 1970 = 1)



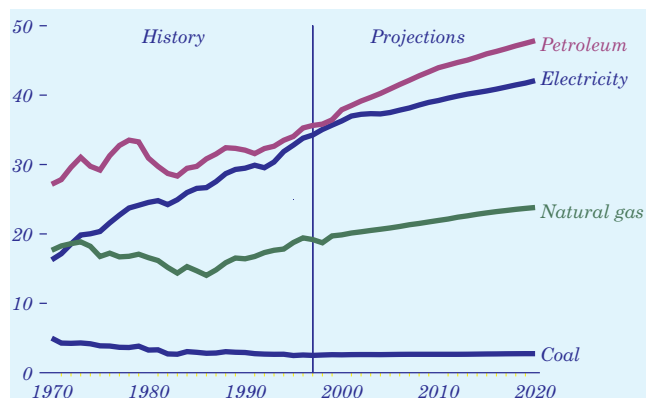
Energy intensity, both as measured by primary energy consumption per dollar of GDP and as measured on a per capita basis, declined between 1970 and the mid-1980s (Figure 44). While the overall GDP-based energy intensity of the economy is projected to continue declining between 1997 and 2020, the decline is not expected to be as rapid as it was in the earlier period, as a result of relatively stable projected energy prices and increased use of electricity-based energy services. As electricity claims a greater share of energy use, projected consumption per dollar of GDP declines at a slower rate, because electricity use contributes both end-use consumption and energy losses to total energy consumption. Between 1997 and 2020, GDP is estimated to increase by 61 percent, compared with a 27-percent increase in primary energy use.

In the *AEO99* forecast, the demand for energy services increases markedly over current levels. The average home in 2020 is expected to be 4 percent larger and to rely more heavily on electricity-based technologies. Annual highway travel and air travel per capita in 2020 are expected to be 20 and 95 percent higher, respectively, than their current levels. Growth in demand for energy services notwithstanding, primary energy intensity on a per capita basis will remain essentially static through 2020, with efficiency improvements in many end-use energy applications making it possible to provide higher levels of service without significant increases in energy use per capita.

Energy Demand

Transportation Petroleum Use Leads the Rise in Energy Consumption

Figure 45. Primary energy use by fuel, 1970-2020 (quadrillion Btu)



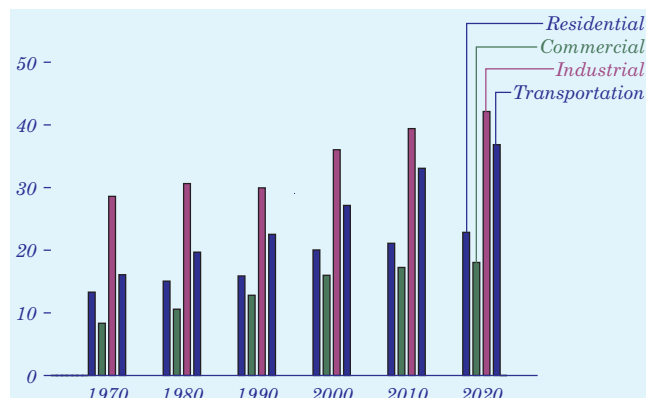
Petroleum products, mainly for transportation, claim the greatest share of primary energy consumption in the *AEO99* forecast (Figure 45). Growth in energy demand in the transportation sector, which averaged 2.0 percent a year during the 1970s, was diminished in the 1980s by rising fuel prices and by new Federal vehicle efficiency standards, which led to an unprecedented 2.1-percent annual increase in average vehicle fuel economy. In the *AEO99* forecast, fuel economy gains slow as a result of stable fuel prices and the absence of new legislative mandates. A growing population and increased travel per capita lead to increases in demand for gasoline throughout the forecast.

Increased competition and technological advances in electricity generation and distribution are expected to reduce the real cost of electricity. Despite low projected prices, however, growth in electricity use is slower than the rapid growth seen in the 1970s. End-use demand for natural gas grows at a slightly slower rate than overall energy demand, in contrast to the recent trend of more rapid growth in the use of gas as the industry was deregulated. Natural gas is projected to meet 19.9 percent of all end-use energy demand requirements in 2020.

End-use demand for renewable energy from sources such as wood, wood wastes, and ethanol increases by 1.2 percent a year. The use of geothermal and solar thermal energy in buildings increases by about 3.6 percent a year but does not exceed 1 percent of energy consumption for space and water heating.

Residential and Commercial Energy Use Is Expected To Increase Modestly

Figure 46. Primary energy use by sector, 1970-2020 (quadrillion Btu)



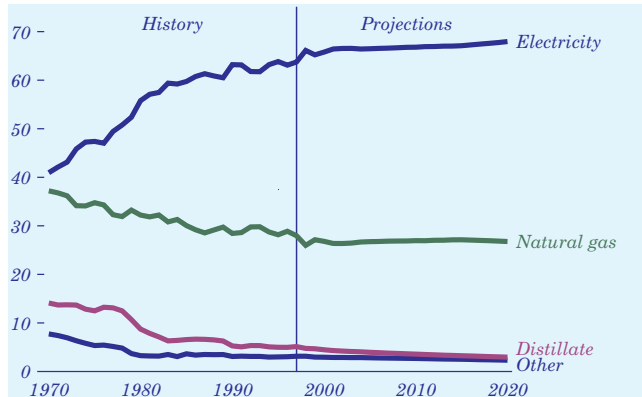
Primary energy use in the reference case is projected to reach 120 quadrillion Btu by 2020, 27 percent higher than the 1997 level. In the early 1980s, as energy prices rose, sectoral energy consumption grew relatively little (Figure 46). Between 1985 and 1997, however, stable energy prices contributed to a marked increase in sectoral energy consumption.

In the forecast, energy demand in the residential and commercial sectors grows at about the same rate as population. Demand for energy in the transportation sector grows more rapidly, driven by estimates of increased per capita travel and slower fuel efficiency gains. Assumed efficiency gains in the industrial sector are projected to cause the demand for primary energy to grow more slowly than GDP.

To help bracket the uncertainty inherent in any long-term forecast, alternative assumptions were used to highlight the sensitivity of the *AEO99* forecast to different oil price and economic growth paths. At the consumer level, oil prices primarily affect the demand for transportation fuels. Oil use for transportation in the high world oil price case is 4.2 percent lower than in the low world oil price case in 2020, as consumer choices favor more fuel-efficient vehicles and a slightly reduced demand for travel services. Varying economic growth affects overall energy demand in each of the end-use sectors to a greater extent [52]. By 2020, high economic growth assumptions result in a 17-percent increase in total annual energy use over its projected level in the low growth case.

Electricity Dominates the Expected Increase in Residential Energy Use

Figure 47. Residential primary energy consumption by fuel, 1970-2020 (percent of total)



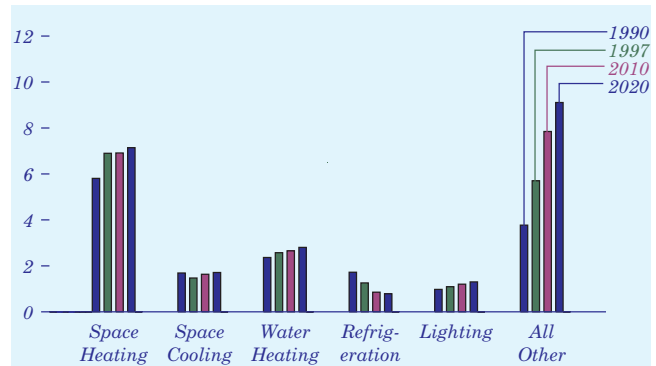
Residential energy consumption is projected to increase by more than 20 percent overall between 1997 and 2020. Most (87 percent) of the growth in total energy use is related to increased use of electricity. Sustained growth in housing in the South, where almost all new homes use central air conditioning, is an important component of the national trend, along with the penetration of consumer electronics, such as home office equipment and security systems (Figure 47).

While its share declines slightly, natural gas use in the residential sector is projected to grow by 0.6 percent a year through 2020. Natural gas prices to residential customers decline in the forecast and are lower than the prices of other fuels, such as heating oil. The number of homes heated by natural gas increases more than the number heated by electricity and oil. Distillate fuel and liquefied petroleum gas (LPG) use are projected to fall, with the number of homes using these fuels for space heating applications expected to decrease over time.

Newly built homes are, on average, larger than the existing stock, with correspondingly greater needs for heating, cooling, and lighting. Under current building codes and appliance standards, however, energy use per square foot is typically lower for new construction than for the existing stock. Further reductions in residential energy use per square foot could result from additional gains in equipment efficiency and more stringent building codes, requiring more insulation, better windows, and more efficient building designs.

Efficiency Improvements Could Slow the Growth in Energy Use for Heating

Figure 48. Residential primary energy consumption by end use, 1990, 1997, 2010, and 2020 (quadrillion Btu)



Energy use for space heating, the most energy-intensive end use in the residential sector, grew by 2.5 percent a year from 1990 to 1997 (Figure 48). Future growth should be slowed by higher equipment efficiency and tighter building codes. Building shell efficiency gains are projected to cut space heating demand in new homes by over 25 percent per household in 2020 relative to the demand in 1997.

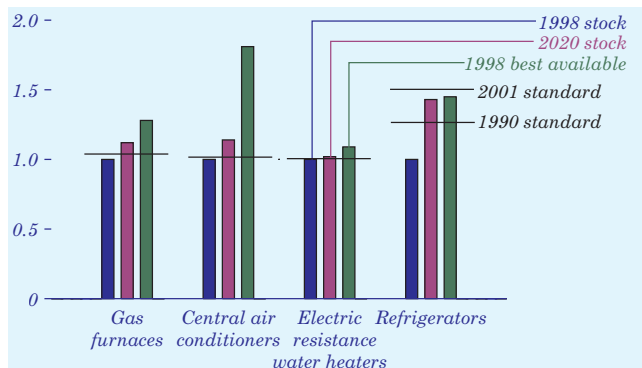
A variety of appliances are now subject to minimum efficiency standards, including heat pumps, air conditioners, furnaces, refrigerators, and water heaters. Current standards for a typical residential refrigerator limit electricity use to 690 kilowatt-hours a year, and revised standards are expected to reduce consumption by another 30 percent by 2002. Energy use for refrigeration has declined by 4.4 percent annually since 1990 and is projected to decline by about 2.0 percent a year through 2020, as older, less efficient refrigerators are replaced with newer models.

The "all other" category, which includes smaller appliances such as personal computers, dishwashers, clothes washers, and dryers, has grown by more than 6 percent a year since 1990 (Figure 48) and now accounts for 30 percent of residential energy use. It is projected to account for 40 percent in 2020, as small electric appliances continue to penetrate the market. The promotion of voluntary standards, both within and outside the appliance industry, is expected to forestall even larger increases. Even so, the "all other" category is expected to exceed other components of residential demand by 2020.

Commercial Sector Energy Demand

Higher Efficiency, Lower Energy Intensity Are Expected for Appliances

Figure 49. Efficiency indicators for selected residential appliances, 1998 and 2020 (index, 1998 stock efficiency =1)

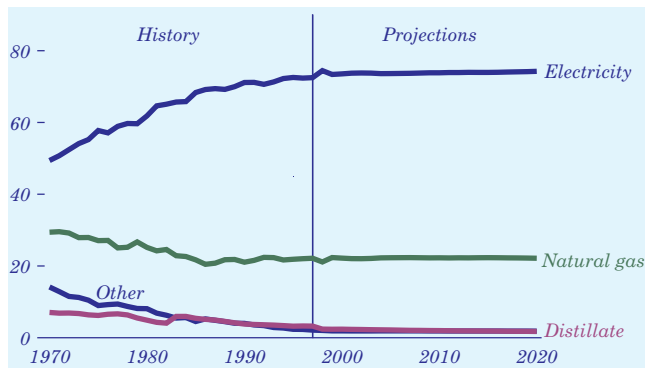


The *AEO99* reference case projects an increase in the stock efficiency of residential appliances, as stock turnover and technology advances in most end-use services combine to reduce residential energy intensity over time. For most appliances covered by the National Appliance Energy Conservation Act of 1987, the most recent Federal efficiency standards are higher than the 1998 stock, ensuring an increase in stock efficiency (Figure 49) without any additional new standards. Future updates to the Federal standards could have a significant effect on residential energy consumption, but they are not included in the reference case. Proposed rules for new efficiency standards for clothes washers and water heaters are expected to be announced by March 1999, and several other product announcements are expected by spring 2000.

For almost all end-use services, technologies now exist that can significantly curtail future energy demand if they are purchased by consumers. The most efficient technologies can provide significant long-run savings in energy bills, but their higher purchase costs tend to restrict their market penetration. For example, condensing technology for natural gas furnaces, which reclaims heat from exhaust gases, can raise efficiency by more than 20 percent over the current standard; and variable-speed compressors for air conditioners and refrigerators can increase their efficiency by 50 percent or more. In contrast, there is little room for efficiency improvements in electric resistance water heaters, because the technology is approaching its thermal limit.

Little Change Is Projected for Commercial Energy Fuel Mix

Figure 50. Commercial nonrenewable primary energy consumption by fuel, 1970-2020 (percent of total)

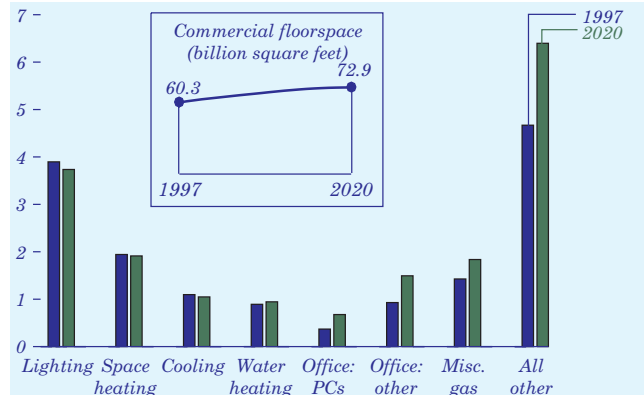


Projected energy use trends in the commercial sector show stable shares for all fuels, with growth in overall consumption slowing from its pace over the past two decades (Figure 50). Slow growth (0.7 percent a year) is expected in the commercial sector, for two reasons. Commercial floorspace is projected to grow by only 0.8 percent a year between 1997 and 2020, compared with an average of 1.5 percent a year over the past two decades. Lower growth in floorspace reflects the slowing population growth expected after 2000. Additionally, energy consumption per square foot is projected to decline by 0.1 percent a year, as a result of efficiency standards, voluntary government programs aimed at improving efficiency, and other technology improvements.

Electricity accounts for nearly three-fourths of commercial primary energy consumption throughout the forecast. Expected efficiency gains in electric equipment are offset by continuing penetration of new technologies and greater use of office equipment. Natural gas accounts for 22 percent of commercial energy consumption in 1997 and maintains that share throughout the forecast. Distillate fuel oil makes up only 3 percent of commercial demand in 1997, down from 6 percent in the years before deregulation of the natural gas industry. The fuel share projected for distillate drops to 2 percent in 2020, as natural gas continues to compete for space and water heating uses. With stable prices projected for conventional fuels, no appreciable growth in the share of renewable energy in the commercial sector is anticipated.

New Energy Uses Lead Projected Growth in Commercial Demand

Figure 51. Commercial primary energy consumption by end use, 1997 and 2020 (quadrillion Btu)

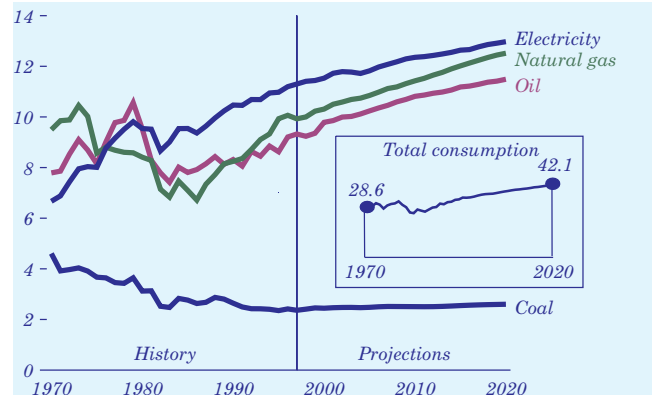


Through 2020, lighting remains the most important individual end use in the commercial sector [53]. Energy use for lighting declines slightly in the forecast as more energy-efficient lighting equipment and more efficient generating technologies are adopted. Efficiency also improves for space heating, space cooling, and water heating, moderating the growth in overall commercial sector energy demand. Increasing building shell efficiency, which affects the energy required for space heating and cooling, contributes to the trend (Figure 51).

The highest growth rates are expected for end uses that have not yet saturated the commercial market. Energy use for personal computers grows by 2.7 percent a year and for other office equipment, such as fax machines and copiers, by about 2.1 percent a year. The growth in electricity use for office equipment reflects a trend toward more powerful equipment, the response to a projected decline in real electricity prices, and an increase in the market for commercial electronic equipment. Natural gas use for such miscellaneous uses as cooking, district heating, and self-generated electricity is expected to grow by 1.1 percent a year. New telecommunications technologies and medical imaging equipment increase electricity demand in the “all other” end use category, which also includes ventilation, refrigeration, minor fuel consumption, service station equipment, and vending machines. Growth in the “all other” category is expected to slow somewhat in later years as emerging technologies achieve greater market penetration.

Increasing Share of Natural Gas Use Is Projected for Industry

Figure 52. Industrial primary energy consumption by fuel, 1970-2020 (quadrillion Btu per year)



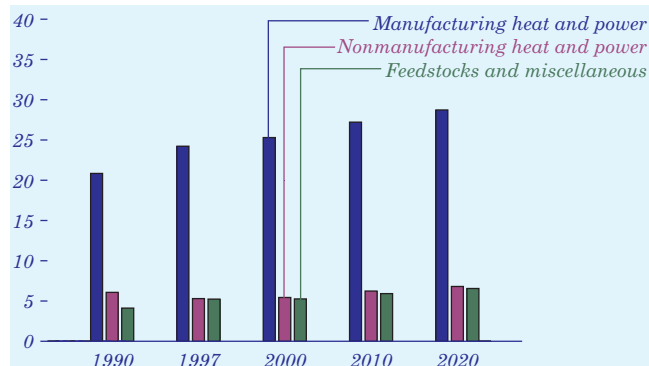
From 1970 to 1986, with demand for coking coal reduced by declines in steel production and natural gas use falling as a result of end-use restrictions and curtailments, electricity’s share of industrial energy use increased from 23 percent to 35 percent. The natural gas share fell from 33 percent to 25 percent, and coal’s share fell from 16 percent to 10 percent. After 1986, natural gas began to recover its share as end-use regulations were lifted and supplies became more certain and less costly. The *AEO99* projections of plentiful supplies and stable prices allow natural gas to increase its current share of industrial energy consumption.

Primary energy use in the industrial sector—which includes the agriculture, mining, and construction industries in addition to traditional manufacturing—increases by 0.8 percent a year in the forecast (Figure 52). Electricity (for machine drive and some production processes) and natural gas (given its ease of handling) are the major energy sources for the industrial sector. Industrial delivered electricity use is projected to increase by 29.8 percent, as competition in the generation market keeps electricity prices low. Relatively low prices are also projected for natural gas, resulting in consumption that is 26.2 percent over its 1997 level by 2020. Industrial petroleum use grows by 23.2 percent over the same period. Coal use increases slowly, by 0.4 percent a year, as new steelmaking technologies continue to reduce demand for metallurgical coal, offsetting the modest growth in coal use for boiler fuel and as a substitute for coke in traditional steelmaking.

Industrial Sector Energy Demand

Manufacturing Heat and Power Dominate Industrial Energy Use

Figure 53. Industrial primary energy consumption by industry category, 1990-2020 (quadrillion Btu per year)



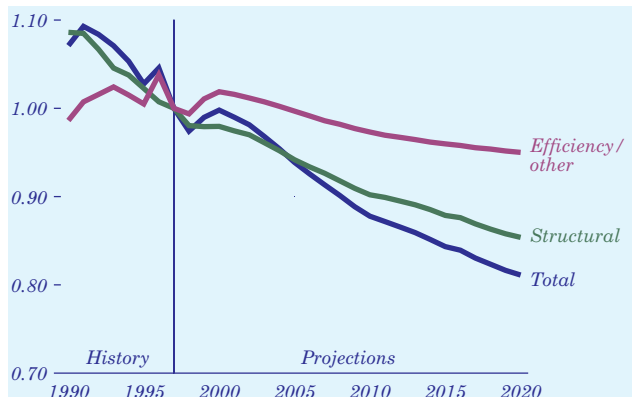
More than two-thirds of all the energy consumed in the industrial sector is used to provide heat and power for manufacturing; the remainder is approximately equally distributed among nonmanufacturing heat and power and consumption as feedstocks (raw materials) and other miscellaneous uses (Figure 53).

Petroleum refining, chemicals, and pulp and paper are the largest end-use consumers of energy for heat and power in the manufacturing sector. These three energy-intensive industries used 8.7 quadrillion Btu in 1997. The major fuels used in petroleum refineries are still gas, natural gas, and petroleum coke. In the chemical industry, natural gas accounts for two-thirds of the energy consumed for heat and power. The pulp and paper industry uses the most renewables, in the form of wood and spent liquor.

A major use of energy in the nonmanufacturing industries is for diesel-powered off-road equipment, such as mine excavation equipment, farm tractors, and bulldozers. The construction industry uses asphalt and road oil for paving and roofing. By 2020, nonmanufacturing output is projected to be 40.9 percent higher and delivered energy consumption (including asphalt and road oil) 38.3 percent higher than their 1997 levels. Total feedstock use is expected to increase by 19.8 percent. Natural gas is the fastest growing feedstock, increasing by 23.4 percent between 1997 and 2020.

Changing Industrial Output Leads the Decline in Energy Intensity

Figure 54. Industrial delivered energy intensity by component, 1990-2020 (index, 1997 = 1)

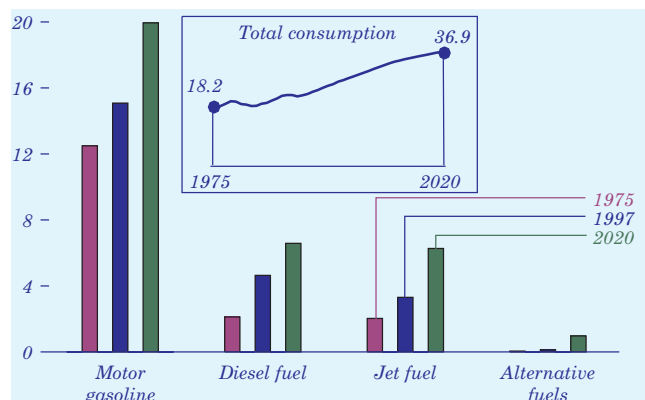


Changes in industrial energy intensity (consumption per unit of output) can be separated into two effects. One component reflects underlying increases in equipment and production efficiencies; the other arises from structural changes in the composition of manufacturing output. Since 1970, the use of more energy-efficient technologies, combined with relatively low growth in the energy-intensive industries, has moderated growth in industrial energy consumption. Thus, despite a 44 percent increase in industrial output, total energy use in the sector has grown by only 12 percent since 1977. These basic trends are expected to continue.

The share of total industrial output attributed to the energy-intensive industries falls from 23 percent to 19 percent from 1997 to 2020. Thus, even if no specific industry experienced a decline in intensity, aggregate industrial intensity would decline. Figure 54 shows projected changes in energy intensity due to structural effects and efficiency effects separately [54]. Over the forecast period, industrial delivered energy intensity drops by 19 percent, and the changing composition of industrial output alone results in approximately a 15-percent drop. Thus, more than two-thirds of the change in delivered energy intensity for the sector is attributable to structural shifts and the remainder to changes in energy intensity associated with increases in equipment and production efficiencies.

Low Prices Are Projected To Boost Gasoline Consumption

Figure 55. Transportation energy consumption by fuel, 1975, 1997, and 2020 (quadrillion Btu)



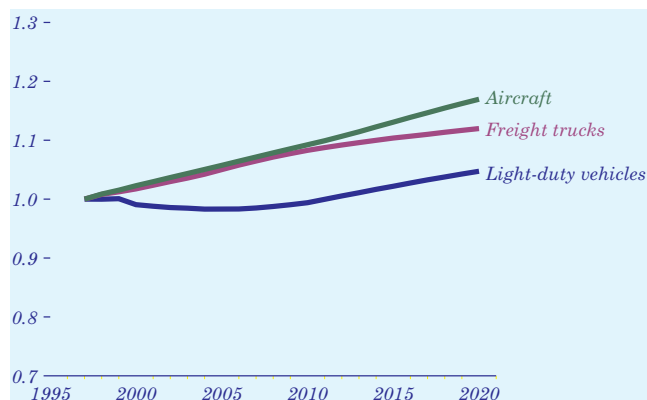
By 2020, total energy demand for transportation is expected to be 36.9 quadrillion Btu, compared with 25.0 quadrillion Btu in 1997 (Figure 55). Petroleum products dominate energy use in the sector. Motor gasoline use, increasing by 1.2 percent a year in the reference case, makes up more than half of transportation energy demand. Alternative fuels are projected to displace about 500,000 barrels of oil equivalent a day [55] by 2020 (about 5 percent of light-duty vehicle fuel consumption), in response to current environmental and energy legislation intended to reduce oil use. Gasoline's share of demand is sustained, however, by low projected gasoline prices and slower fuel efficiency gains in conventional light-duty vehicles (cars, vans, pickup trucks, and utility vehicles) than was achieved during the 1980s.

Assumed industrial output growth of 1.9 percent a year through 2020 leads to an increase in freight transport, with a corresponding increase in diesel use of 1.5 percent a year. Economic growth and low projected jet fuel prices yield a 3.8-percent annual increase in air travel, causing jet fuel use to increase by 2.8 percent a year.

In the forecast, energy prices directly affect the level of oil use through travel costs and average vehicle fuel efficiency. Most of the projected price sensitivity is seen as variations in motor gasoline use in light-duty vehicles, because the stock of light-duty vehicles turns over more rapidly than the stock for other modes of travel. In the high oil price case, gasoline use increases by only 1.1 percent a year, compared with 1.4 percent a year in the low oil price case.

Fuel Efficiency Grows, Despite Increasing Vehicle Horsepower

Figure 56. Transportation stock fuel efficiency by mode, 1997-2020 (index, 1997 = 1)



Projected fuel efficiency improves at a slower rate through 2020 than in the 1980s (Figure 56), with light-duty vehicle efficiency standards assumed to stay at current levels. Projected low fuel prices and higher personal income [56] increase the demand for larger, more powerful vehicles. Average horsepower for new cars in 2020 is 63 percent above the 1997 level (Table 3), but the use of advanced technologies and materials keeps new vehicle fuel economy from declining. New advanced technologies, such as gasoline fuel cells and direct fuel injection and electric hybrids for both gasoline and diesel engines, are projected to boost fuel economy levels gradually through 2020, by about 1 to 2 miles per gallon.

From 1990 to 1997, the horsepower of compact sport utility vehicles (medium light trucks) increased faster than that of standard sport utility vehicles (large light trucks)—3.0 percent vs. 2.6 percent a year. If it continues, this trend will lead to higher horsepower for medium than for large light trucks by 2020.

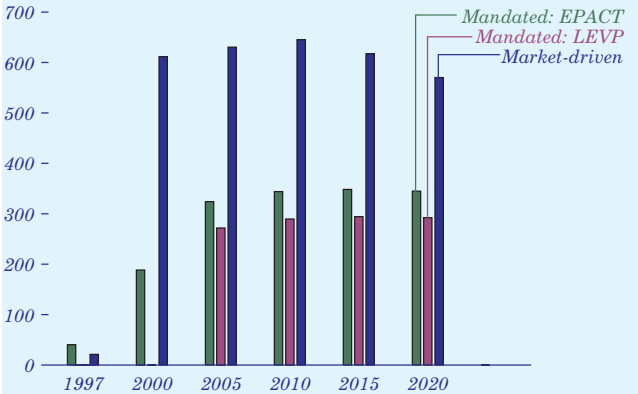
Table 3. New car and light truck horsepower ratings and market shares, 1990-2020

Year	Cars			Light trucks		
	Small	Medium	Large	Small	Medium	Large
1990						
Horsepower	118	141	164	132	165	175
Sales share	0.60	0.28	0.12	0.50	0.38	0.12
1997						
Horsepower	139	167	187	156	185	196
Sales share	0.57	0.30	0.13	0.32	0.57	0.11
2010						
Horsepower	192	224	270	222	262	249
Sales share	0.58	0.29	0.14	0.34	0.50	0.16
2020						
Horsepower	232	263	307	275	307	291
Sales share	0.58	0.28	0.14	0.34	0.49	0.17

Transportation Sector Energy Demand

Electric Vehicles Are Projected To Gain AFV Market Share

Figure 57. Alternative-fuel vehicle sales by type of demand, 1997-2020 (thousand vehicles sold)



Sales of alternative-fuel vehicles (AFVs) as a result of legislative mandates at the Federal level—under the Energy Policy Act of 1992 (EPACT)—and at the State level—under the Low Emission Vehicle Program (LEVP)—are expected to reach about 0.64 million units in 2020 (Figure 57). AFV acquisitions mandated for fleets under EPACT, predominantly fueled by compressed natural gas (CNG) or liquefied petroleum gas, represent the earliest legislated sales. Vehicles that use gaseous fuels continue to capture a large share of the AFV market through 2020 (Table 4).

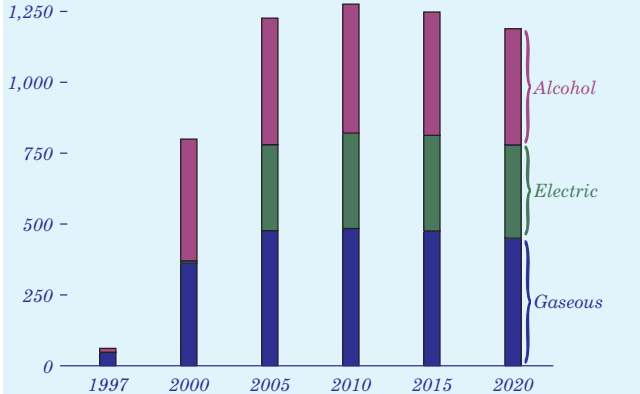
Implementation of LEVP regulations is assumed to begin in 2003 for California, Massachusetts, and New York. LEVP legislated sales are expected to total 292,000 units in 2020, boosting electric vehicles to about 25 percent of AFV sales. Market-driven sales [57] exceed mandated sales of AFVs by 2000 as a result of AFV corporate average fuel economy (CAFE) credits available to auto manufacturers under the Alternative Motor Fuels Act.

Table 4. Shares of the alternative-fuel light-duty vehicle market by technology type, 2020 (percent)

Technology	Market share	Technology	Market share
<i>Dedicated internal combustion</i>		<i>Flex fuel internal combustion</i>	
Alcohol	11.0	Alcohol	23.0
CNG	17.1	CNG	4.1
LPG	13.6	LPG	2.5
Electric	24.8	Electric hybrid	2.4
Fuel cell	1.5		

AFVs Are Projected at 8 Percent of All Vehicle Sales in 2020

Figure 58. Alternative-fuel light-duty vehicle sales by fuel type, 1997-2020 (thousand vehicles sold)



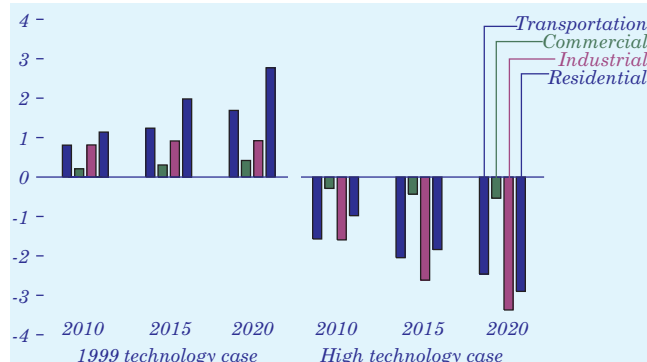
In the reference case, total AFV sales reach approximately 1.21 million units, or 8.1 percent of all vehicle sales, in 2020 (Figure 58). The use of light-duty AFVs is expected to reduce carbon emissions by 1 million metric tons of carbon by 2020. Vehicles that use gaseous fuels are already being sold by manufacturers at prices \$3,000 to \$4,000 above those for gasoline vehicles. Their limited range (about two-thirds that of gasoline vehicles) makes them good candidates for centrally fueled fleet applications. Because the large fuel tanks required to maintain vehicle range restrict both trunk and passenger space, the market potential for gaseous fuel AFVs for private use is limited to larger vehicles.

Electric vehicles are currently being developed by several automobile manufacturers, but large numbers of sales are not expected until LEVP mandates begin. Sales of dedicated electric vehicles—98 percent of which originate from LEVP mandates—are projected to reach nearly 299,000 units in 2020.

“Flex fuel” vehicles, which can use any combination of ethanol, methanol, and gasoline, are expected to make up 23 percent of AFV sales in 2020. The range, fuel efficiency, and performance of these vehicles are similar to those of conventional gasoline vehicles, and their incremental production cost is currently less than \$500, although manufacturers are now selling them at cost to meet CAFE standards. Cellulosic ethanol is expected to displace corn-based ethanol by 2001, resulting in lower fuel costs for flex-fuel vehicles.

New Efficient Technologies Could Save Energy in All Sectors

Figure 59. Variation from reference case primary energy use by sector in two alternative technology cases, 2010, 2015, and 2020 (quadrillion Btu)



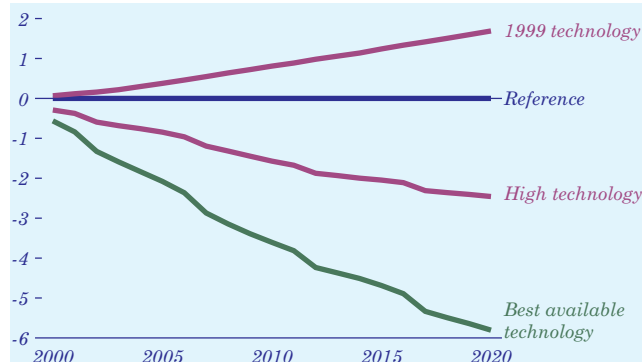
The availability and market penetration of new, more efficient technologies are uncertain. Alternative cases for each sector, based on a range of assumptions about technological progress, show the effects of the assumptions (Figure 59). The alternative cases assume that current equipment and building standards are met but do not include feedback effects on energy prices or on economic growth.

For the residential and commercial sectors, the 1999 technology case holds equipment and building shell efficiencies at 1999 levels. The best available technology case assumes that the most energy-efficient equipment and best residential building shells available are chosen for new construction each year regardless of cost, and that efficiencies of existing residential and all commercial building shells improve from their reference case levels. The high technology case assumes earlier availability, lower costs, and higher efficiencies for more advanced technologies than in the reference case.

The 1999 technology cases for the industrial and transportation sectors and the high technology case for the industrial sector use the same assumptions used for the buildings sector. The high technology case for the transportation sector includes reduced costs for advanced technologies and improved efficiencies, comparable to those assumed in a recent Department of Energy (DOE) interlaboratory study for air, rail, marine, and freight travel and provided by the DOE Office of Energy Efficiency and Renewable Energy and American Council for an Energy-Efficient Economy for light-duty vehicles [58].

Potential Efficiency Gains Are Significant for Residential Users

Figure 60. Variation from reference case primary residential energy use in three alternative cases, 2000-2020 (quadrillion Btu)



The AEO99 reference case forecast includes the projected effects of several different policies aimed at increasing residential end-use efficiency. Examples include minimum efficiency standards and voluntary energy savings programs designed to promote energy efficiency through innovations in manufacturing, building, and mortgage financing. In the 1999 technology case, which assumes no further increases in the efficiency of equipment or building shells beyond that available in 1999, 7.4 percent more energy would be required in 2020 (Figure 60).

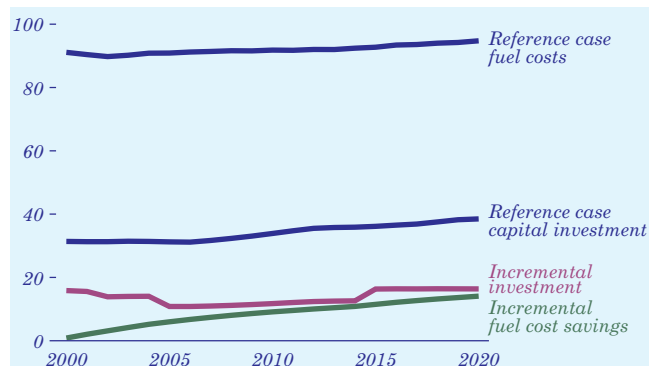
In the best available technology case, assuming that the most energy-efficient technology considered is always chosen regardless of cost, energy use is 25.4 percent lower than in the reference case in 2020, and household primary energy use is 30.5 percent lower than in the 1999 technology case in 2020.

The high technology case does not constrain consumer choices. Instead, the most energy-efficient technologies are assumed to be available earlier, with lower costs and higher efficiencies. The consumer discount rates used to determine the purchased efficiency of all residential appliances in the high technology case do not vary from those used in the reference case; that is, consumers value efficiency equally across the two cases. Energy savings in this case relative to the reference case reach 10.8 percent in 2020; however, the savings are not as great as those in the best available technology case.

Energy Demand in Alternative Technology Cases

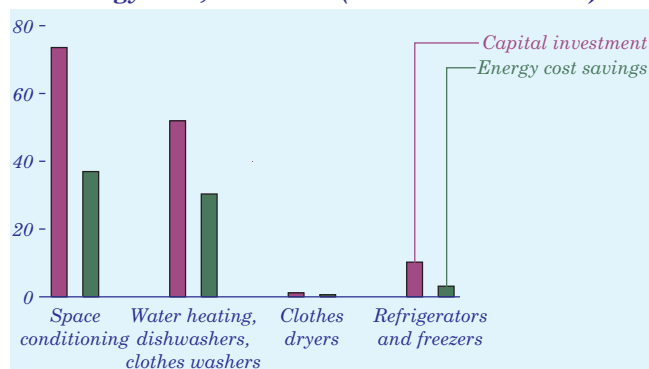
Investment Costs Could Outstrip Residential Energy Cost Savings

Figure 61. Cost and investment changes for selected residential appliances in the best available technology case, 2000-2020 (billion 1998 dollars)



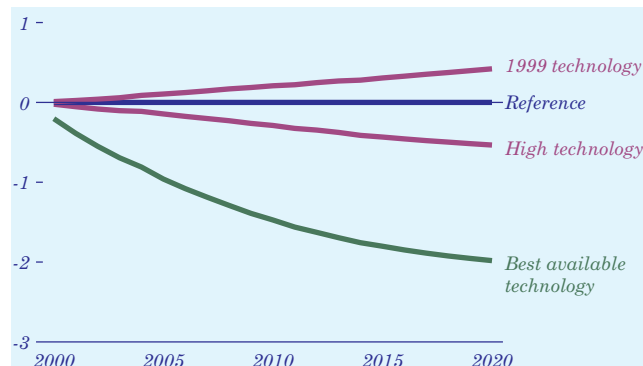
In the best available technology case, which requires the purchase of the most efficient equipment available, residential energy expenditures are lower but capital investment costs are higher (Figures 61 and 62). This case captures the effects of installing the most efficient (usually the most expensive) equipment at reference case turnover rates, regardless of economic considerations. An incremental investment of \$137 billion [59] reduces residential delivered energy use by more than 22 quadrillion Btu—saving consumers more than \$71 billion in energy expenditures—through 2020. Water heating and space conditioning show the greatest potential for savings, but at a substantial investment cost. In place of conventional technologies, such as electric resistance water heaters, natural gas and electric heat pump water heaters, and horizontal-axis washing machines can substantially cut the amount of energy needed to provide hot water services.

Figure 62. Present value of investment and savings for residential appliances in the best available technology case, 2000-2020 (billion 1998 dollars)



AE099 Reference Case Includes Gains in Commercial Energy Efficiency

Figure 63. Variation from reference case primary commercial energy use in three alternative cases, 2000-2020 (quadrillion Btu)

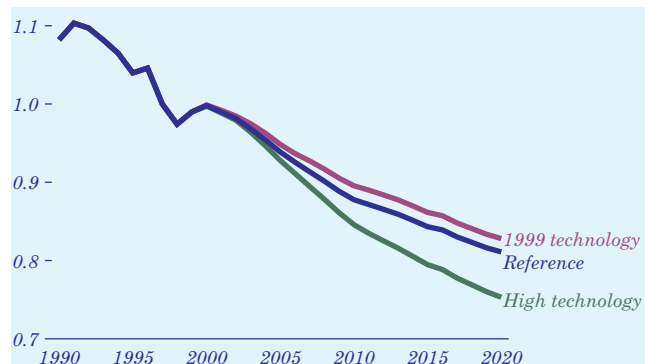


The AEO99 reference case incorporates efficiency improvements for commercial equipment and building shells, contributing to a decline in commercial energy intensity of 0.1 percent a year over the forecast. The 1999 technology case assumes that future equipment and building shells will be no more efficient than those available in 1999. The high technology case assumes earlier availability, lower costs, and higher efficiencies for more advanced equipment than in the reference case. In addition, building shells are assumed to improve at a faster rate than in the reference case. In comparison, the best available technology case assumes that only the most efficient technologies considered in AEO99 will be chosen, regardless of cost, and that building shells will improve at the same rate assumed in the high technology case.

Energy use in the 1999 technology case is 2.3 percent higher than in the reference case by 2020 (Figure 63), with commercial primary energy intensity stable through 2020. In the high technology case there is an additional 3.0-percent energy savings in 2020, and primary energy intensity falls by 0.2 percent a year from 1997 to 2020. Allowing the purchase of only the most efficient equipment in the best available technology case yields energy use that is 11.0 percent lower than energy use in the reference case by 2020. Commercial primary energy intensity declines more rapidly in this case than in the high technology case, by 0.6 percent a year.

Trends in Energy Intensity Vary by 50 Percent in Alternative Cases

Figure 64. Industrial primary energy intensity in two alternative technology cases, 1990-2020 (index, 1997 = 1)



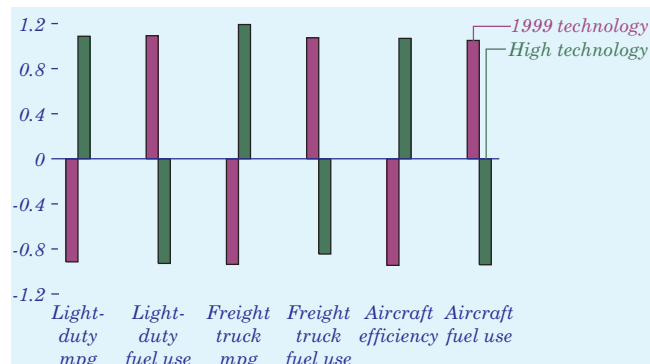
Projected efficiency gains in both energy-intensive and non-energy-intensive industries provide improvement in energy intensity. The growth in machinery and equipment production, driven primarily by investment and export-related demand, is a key factor: these less energy-intensive industries grow 48 percent faster than the industrial average (2.8 percent vs. 1.9 percent a year).

In the high technology case, 3.4 quadrillion Btu less energy is used in 2020 than for the same level of output in the reference case. Industrial primary energy intensity declines by 1.4 percent a year through 2020 in this case, compared with a 1.0-percent annual decline in the reference case (Figure 64). While the individual industry intensities decline about twice as rapidly in the high technology case as in the reference case, the aggregate intensity falls less rapidly, because the composition of industrial output is the same in the two cases.

In the 1999 technology case, industry consumes 0.9 quadrillion Btu more energy in 2020 than in the reference case. Energy efficiency remains at the level achieved in 1999 new plants, but average efficiency still improves as old plants are retired. Aggregate industrial energy intensity declines by 0.9 percent a year because of reduced efficiency gains and changes in industrial structure. The composition of industrial output accounts for 86 percent of the change in aggregate industrial energy intensity, compared with 77 percent in the reference case.

More Improvement in Fuel Efficiency Is Possible for Transportation Uses

Figure 65. Changes in key components of the transportation sector in two alternative cases, 2020 (percent change from reference case)



Two alternative cases are examined to bracket the potential impacts of technology improvements in the transportation sector. The 1999 technology case holds new fuel efficiencies for light-duty vehicles, freight trucks, and aircraft at 1999 levels throughout the forecast, resulting in average stock efficiencies for light-duty vehicles that are as much as 8.4 percent lower than those in the reference case in 2020. As a result, fuel use in 2020 is 2.8 quadrillion Btu (7.5 percent) higher than in the reference case (Figure 65). The increase in fuel use is attributable primarily to light-duty vehicles (55 percent of the total increase), followed by aircraft (17 percent) and freight trucks (16 percent).

The high technology case assumes cost and performance criteria provided by the DOE Office of Energy Efficiency and Renewable Energy and American Council for an Energy-Efficient Economy for light-duty vehicles, and from the efficiency case of the recent interlaboratory study [60] for air, freight, marine, and rail travel, including high-efficiency advanced light-duty diesel vehicles; electric, electric hybrid, and fuel cell light-duty vehicles with higher efficiencies and earlier introduction dates; advanced drag reduction, reduced vehicle weights, and advanced diesel engines for freight trucks, with shorter market penetration times and lower cost-effectiveness criteria; and aircraft with higher fuel efficiency. In the high technology case, total fuel consumption for the transportation sector is 2.9 quadrillion Btu (7.9 percent) lower than the reference case level in 2020.